

The palaeogeographic setting and the local environmental impact of the 130 ka Falconiera tuff-cone eruption (Ustica island, Italy)

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Article history

Received July 14, 2016; accepted February 03, 2017.

Subject classification:

Volcanic rocks, Geomorphology, Tuff-cone, Fossils, Sediments.

ABSTRACT

This research focuses on the effects of the last eruption at Ustica, which formed the Falconiera tuff-cone at around 130 ka BP in the north-eastern tip of the island. This eruption was mainly explosive and phreatomagmatic, emplacing a series of pyroclastic surge beds that formed an asymmetric tuff cone. This is the most easily recognizable volcanic edifice on Ustica, although its north-eastern sector has been partially eroded. A section of the feeding conduit is exposed northward, and is composed of lavas that fed the last stages of the eruption characterized by an intracrateric lava lake and a Strombolian scoria-fallout deposit. The eruption occurred during Upper Pleistocene Marine Isotopic Substage 5.5, a warm period characterized by a high sea-level stand (6 ± 3 m above the present sea level in stable areas) and the diffusion of subtropical flora and fauna across the Mediterranean sea. This eruption slightly modified the morphology of Ustica, but impacted both marine and terrestrial environments, burying beach deposits rich in mollusk shells (i.e. *Strombus bubonius*, *Conus testudinarius*, *Brachidontes puniceus*), colonies of corals (*Cladocora caespitosa*) and subaerial plants (*Chamaerops humilis*). These organisms, found in some cases in their life position, along with other lines of evidence, provide information on the palaeogeography of this sector of the island at the time of the eruption and on the local impact of this event on the environment.

1. Introduction

The island of Ustica is the top of a vast submerged volcanic complex that rises more than 2,000 m from the bottom of the Tyrrhenian Sea on thinned continental crust [15-20 km; Giese and Morelli, 1973]. It is situated 60 km north of the Sicily coast, west of the Aeolian arc, and a few km east of the E-W trending Anchise seamount (Figure 1). The emergent part of Ustica volcano covers an area of less than 10 km² and reaches a maximum elevation of 248 m asl. It is mainly composed of volcanic rocks, and subordinately

of marine and continental sedimentary deposits. Volcanic rocks are the product of both subaqueous and subaerial effusive and explosive eruptions [Romano and Sturiale, 1971; Cinque et al., 1988; de Vita, 1993; de Vita et al. 1995; 1998]. Marine sedimentary rocks consist of clayey sands, organogenic and detrital fossiliferous limestones, and carbonate concretions. They were sedimented during Middle-Upper Pleistocene sea level high-stands that were related to glacio-eustatic movements that also generated five orders of marine terraces [de Vita and Orsi, 1994]. Continental sedimentary rocks are detrital aprons, sometimes pedogenized, landslide deposits and detrital fans, related to the more recent geomorphological evolution of the island [de Vita, 1993].

The Ustica volcanic rocks have a Na-alkaline affinity, ranging in composition from alkali-basalts to alkali-trachyte, with a compositional gap in the field of benmoreite [55-60 wt % SiO₂; de Vita, 1993; Peccerillo, 2005]. Mafic rocks, in particular, cross the line that separates the subalkaline and the alkaline fields and display a transitional character [Peccerillo, 2005]. Moreover Ustica basalts are characterized by incompatible elements and Sr-isotope ratios that are intermediate between intraplate basalts from Pantelleria and calc-alkaline mafic rocks from Aeolian islands [Cinque et al., 1988]. This led Trua et al. [2003] to conclude that the Ustica magmas were generated by an intra-plate type mantle, contaminated by subduction fluids or melts during the fast rollback of the Ionian slab. The origin of Ustica volcanism has been related to the activation of left-transensional deep faults, linked to the deformational events that accompanied the anticlockwise rotation of the Italian peninsula and the opening of the Tyrrhenian basin, in the course of the

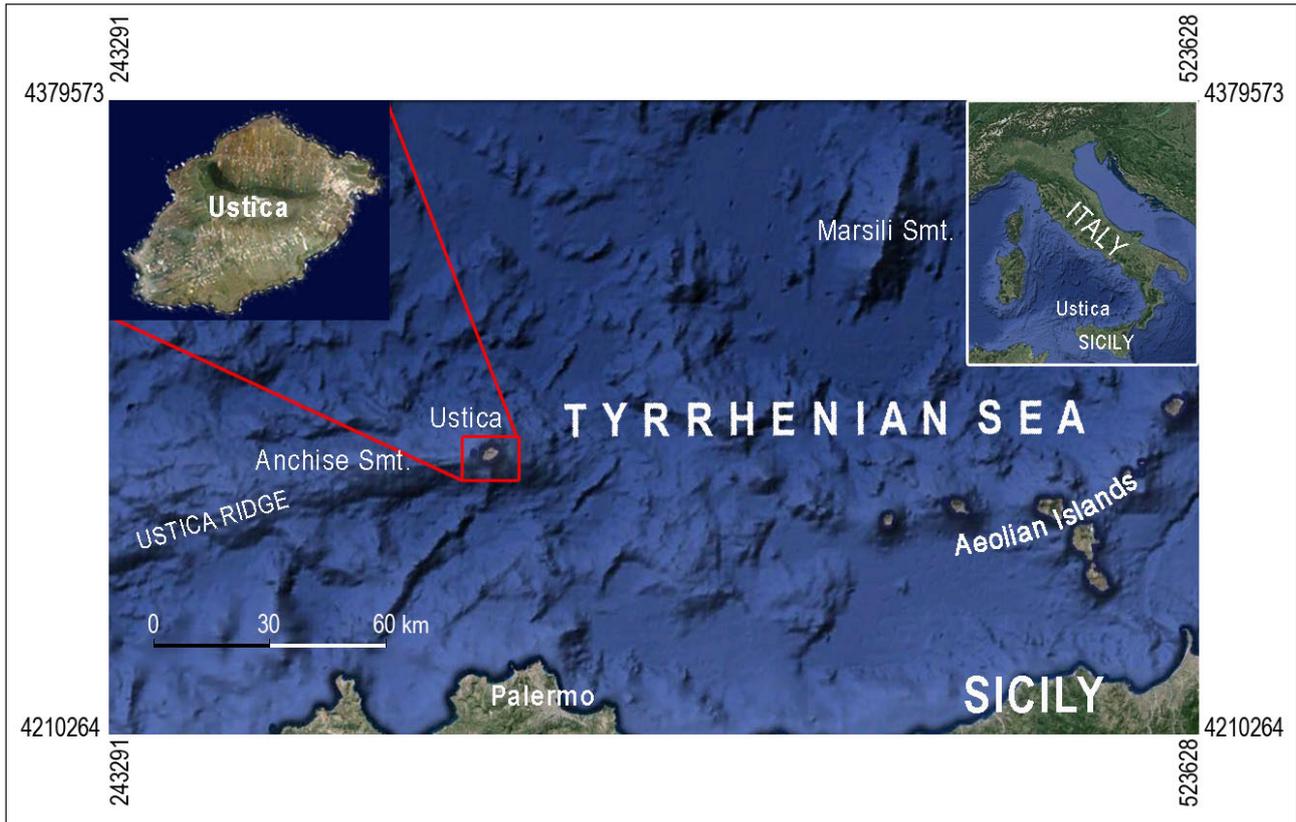


Figure 1. Morphological map of Southern Tyrrhenian Sea (modified after Google Earth; Image Landsat, Data SIO, NOAA, US Navy, NGA, GEBCO, Map Data © 2016). Coordinate system UTM WGS84, 33S. Left top-angle: Ustica Island image from the same source.

complex interaction between the African and Eurasian plates [de Vita et al., 1995].

A Pleistocene age has been assumed for the birth of the Ustica volcanic complex [Barberi et al., 1969; Barberi and Innocenti, 1980], whereas more recent stratigraphic, structural and geochronological studies demonstrate that the exposed rocks were formed between 750 and 130 ky [de Vita et al., 1998]. The present morphology of the island is the result of the prolonged interplay between volcanism, tectonism, eustatism and exogenous morphodynamic processes, that generated volcanic edifices and structures, and level surfaces, displaced at variable height above sea level, and produced different deposits and erosional features.

This paper focuses on the effects of the last eruption on Ustica, which formed the Falconiera tuff-cone at around 130 ka BP in the north-eastern tip of the island. This eruption slightly modified the Ustica morphology, but impacted on both marine and terrestrial environments, burying beach deposits rich in mollusk shells, colonies of corals and subaerial plants. The discovery of these organisms, in some cases still in their vital position, along with other geological, volcanological and geomorphological evidence, allowed the reconstruction of the palaeogeography of this sector

of the island at the time of the eruption, and the local environmental impact of this event.

2. Geological framework

Volcanism at Ustica started with the activation of a series of submarine vents along ENE-WSW trending, deep transtensional faults that allowed magmas to quickly reach the surface, directly from their mantle source, feeding effusive eruptions [Barberi et al., 1969; Barberi and Innocenti, 1980; de Vita, 1993]. Following this, the activity concentrated into a main seamount, whose products reached the surface in the Middle Pleistocene, making Ustica the only volcano of anorogenic origin that has emerged from the Southern Tyrrhenian Sea (Figure 2). The emergence of the island coincided with the birth of the Mt. Guardia dei Turchi subaerial basaltic stratovolcano at about 520 ka [de Vita et al., 1998; Figure 2], whose initial eruptions occurred subaqueously and formed pillow-lava flows. Subaerial volcanic activity continued with the formation of the Mt. Costa del Fallo basaltic tuff-cone, which is the second highest peak on the island, and a series of moderately explosive and effusive eruptions, the most recent of which occurred at 475 ka, along the western flank of Mt. Costa del Fallo [de Vita et al., 1998; Figure 2]. After a 50 ky long period of quiescence, during which magma differentiated in a shallow

THE FALCONIERA TUFF-CONE ERUPTION

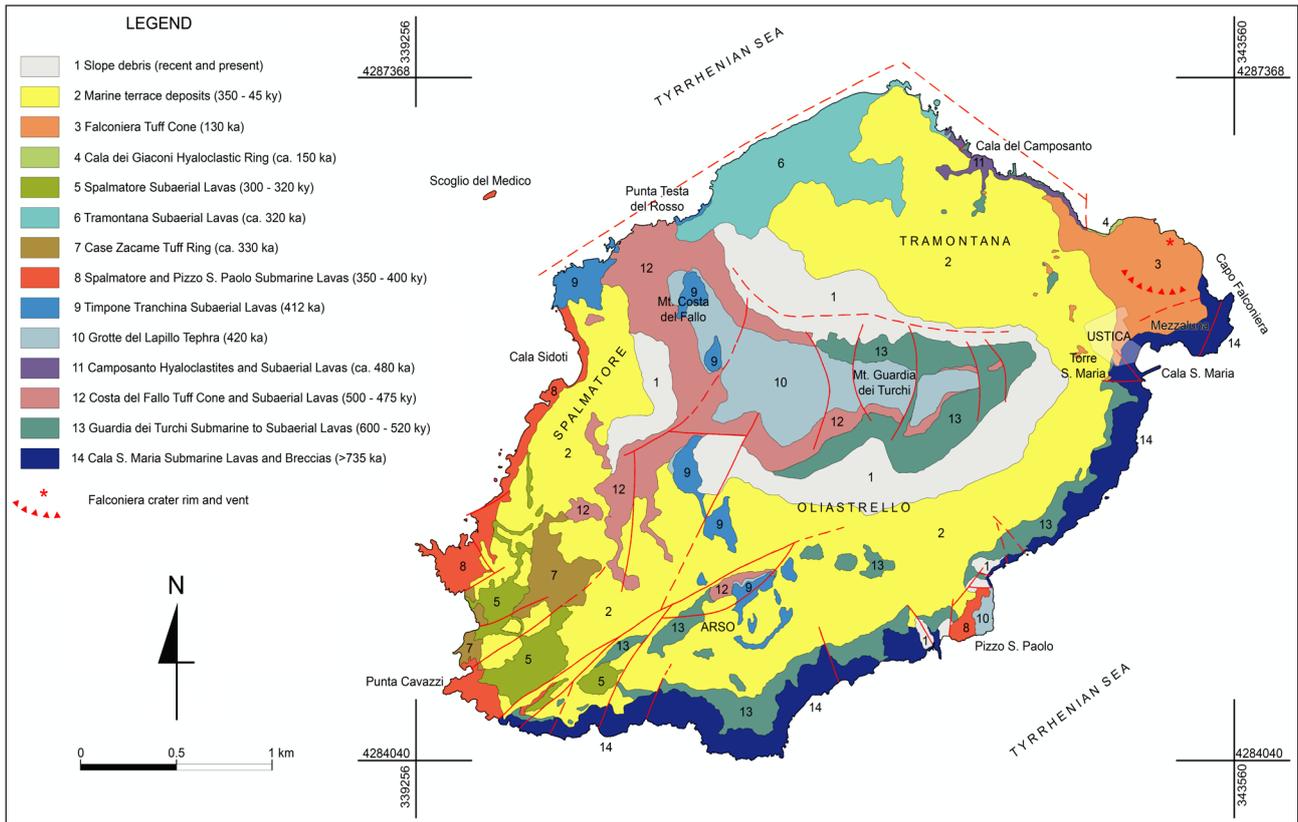


Figure 2. Geological sketch map of Ustica island (modified after de Vita, 1993). Coordinate system UTM WGS84, 33S.

magma chamber, volcanism restarted at 425 ka with the sub-Plinian eruption of the Grotte del Lapillo Tephra [de Vita et al., 1998; Figure 2]. This is the only episode during which trachytic magma was erupted, although shallow intrusions along the southern coast and in the northern offshore [Bellia et al., 2000] were most likely produced by the same magmatic episode. The explosive eruption took place in the present Tramontana plain and was associated with the formation of a small caldera in the northern sector of the island. The tephra produced by this eruption blanketed almost of the island, and formed a thick sequence of pumice lapilli and ash, emplaced by fallout and pyroclastic density currents [de Vita, 1993; de Vita et al., 1995; 1998]. Basaltic magmas were erupted during the following volcanic activity, which produced at least twelve magmatic and phreatomagmatic effusive and explosive eruptions. Most of the deposits generated by these eruptions are exposed in the western and northern sectors of the island and are composed of both subaqueous and subaerial lava flows, hyaloclastites and tuff-ring-forming pyroclastic surge beds (Figure 2). Volcanic activity on the island ceased at around 130 ka, with the explosive Falconiera phreatomagmatic eruption and the formation of an asymmetric tuff cone, which is the most easily recognizable volcanic edifice (Figure 3).

Throughout Ustica's volcanic history, there were several overlapping cycles of marine transgression and

regression, resulting from Middle-Upper Pleistocene glacio-eustatic movements. The sea-level stands related to these oscillations generated typical sedimentary terraces, which were later displaced by tectonism at variable heights from their original position. Five orders of level surfaces have been identified at heights ranging from about 100 m asl for the oldest and highest terrace, to 5 m asl for the most recent and lowest one [Table 1; de Vita and Orsi, 1994; de Vita et al., 1998].

The main deformational lineaments still preserved on Ustica, trend E-W and NE-SW. They were produced by variable tectonic phases, the oldest of which seems to have generated the E-W trending fault system, along which also the older Anchise seamount was generated (Figure 1). Almost all the volcanic vents of the island are aligned along a N60E trending lineament, which represents, together with an associated N25E trending system of *en échelon* faults, the response to a regional state of stress, characterized by sinistral transtension [de Vita et al., 1995]. NW-SE and N-S trending fault systems are subordinated and associated to a less relevant volcanic activity [de Vita, 1993]. The occurrence of marine terraces of variable age at decreasing elevation from the oldest to the youngest, helps in defining the amount of uplift recorded by the island: it has to have been no more than 120 m, at least since the formation of the oldest level surface at 350 ka. During this period relative displacement

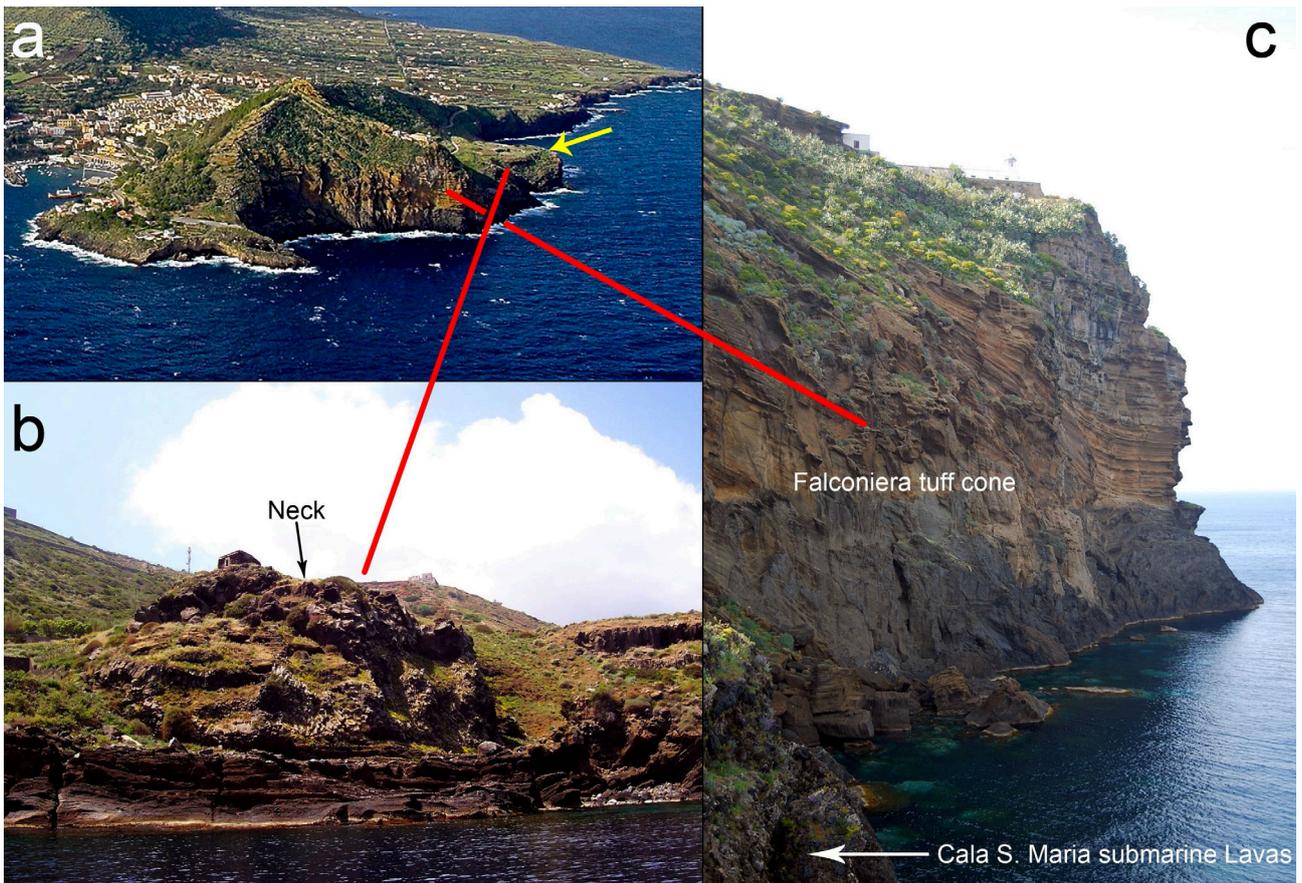


Figure 3. a) The Falconiera Tuff Cone, as seen from the east, with the level surface at 30 m asl (yellow arrow); b) the neck of the edifice; c) the variable degree of palagonitization of the Falconiera deposits, evidenced by colour differences.

| Order | Height (m asl) | Age (ka) |
|-------|----------------|----------|
| I | 80-120 | 350 |
| II | 40-60 | 240±35 |
| III | 30 | 132±6 |
| IV | 10 | 105 |
| V | 5 | 80 |

Table 1. Elevation and age of the marine terraces of Ustica island [after de Vita and Orsi, 1994].

of parts of the entire complex accompanied the general uplift of the island, mostly along the same N60E trending fault planes [de Vita et al., 1995].

3. The Falconiera tuff-cone

In this section are described the results of a detailed geological survey, carried out on the island in order to define the areal distribution of the Falconiera tuff-cone deposits and their stratigraphic relationships with the other exposed units.

3.1 Morphology and stratigraphic position

The Falconiera tuff-cone is a rather well preserved volcanic edifice (Figure 3a), whose original shape,

as deduced from the geometry of the pyroclastic beds that built it up, was an asymmetric cone with higher southern portions. The northern part of the cone is partially missing, likely due to normal erosional processes and syn-depositional collapses, caused by the gravitational instability related to its rapid growth and the action of the sea-waves. The latter generated a level surface, which is presently at an elevation of about 30 m asl, and exposes the neck of the edifice at the bottom of the crater (Figure 3b). The Falconiera tuff-cone reaches a maximum elevation of 158 m asl. Its products cover less than 1 km² and extend northwestward to Cala del Camposanto, and southward to Cala Santa Maria, and partially underlie Ustica village. Other outcrops of limited areal extent are exposed at a distance up to 750 m in the Tramontana plain and in the western peripheral part of the village, up to Torre Santa Maria (Figure 2). The deposits of the Falconiera tuff-cone are the youngest volcanic products on the island, which unconformably overlie all the oldest units, through the interposition of a paleosol in the westernmost exposures, or marine and beach deposits toward north and south-southeast (Figure 4). Marine deposits are composed of loose to weakly cemented, plane-parallel to cross-stratified volcanic sand, with abundant fragments

of shells (lamellibranches and gasteropods) and angular fragments and pebbles of basaltic lavas and tuffs. Beach deposits are mainly loose or weakly cemented gravels and sandy gravels, with flattened and imbricated pebbles of basaltic lavas, conglomerates and tuffs, and interbedded lenses and pockets of fine-to-coarse sands with abundant remnants of marine organisms (whole shells and fragments of lamellibranches and gasteropods), and dispersed blocks of basaltic lavas and conglomerates with volcanic clasts, detrital and organogenic sandy matrix and carbonatic cement. Marine deposits characterized by identical faunal association have been found above the Falconiera tuff-cone deposits in the Mezzaluna outcrop [Buccheri et al., 2014]. Both the lowermost and uppermost marine deposits have been correlated to the Upper Pleistocene Tyrrhenian Stage (Marine Isotopic Substage 5.5) on the basis of their fossil contents [Ruggeri and Buccheri, 1968; Buccheri et al., 2014]. All along the western outcrop area, the Falconiera deposits are overlain by reworked and cultivated, humified slope-debris deposits.

3.2 The volcanic succession

The Falconiera tuff-cone is mainly composed of thinly-stratified and lithified pyroclastic surge beds, characterized by variable thicknesses and grain-sizes,

intercalated at different heights with scoria fall deposits. Lithification is due to the palagonitization of the volcanic glass, which has affected the edifice in a variable degree (Figure 3c). The Falconiera deposits have a maximum thickness of about 130 m close to the top of the hill and thin rapidly radially from the vent area. Coarser-grained beds are 10–20 centimeters thick on average, and thin slightly with distance from the vent. They are usually massive and composed of a coarse-ash matrix with dispersed abundant, lapilli-sized black scoriae and lithic fragments (both cogenetic or accessory). Finer-grained beds are a few centimeters thick and are composed of plane-parallel to cross stratified layers of ash and fine-ash with abundant coarse-ash to lapilli-sized black scoriae and lithic fragments. Scoria fallout deposits are laterally discontinuous (lensoid), due to the erosion by pyroclastic density currents. These deposits are poorly sorted and composed of lapilli to bomb-sized, well vesiculated, black scoriae, poorly porphyritic with small, clear phenocrysts of olivine. A very small amount of lithic fragments has been observed. Impact sags from ballistically emplaced blocks (5–40 cm in diameter) are very common. The dips of the beds are quaquaversal, with inward high-angle and outward low-angle dip directions that vary from the inside toward the outside of the edifice across the cra-

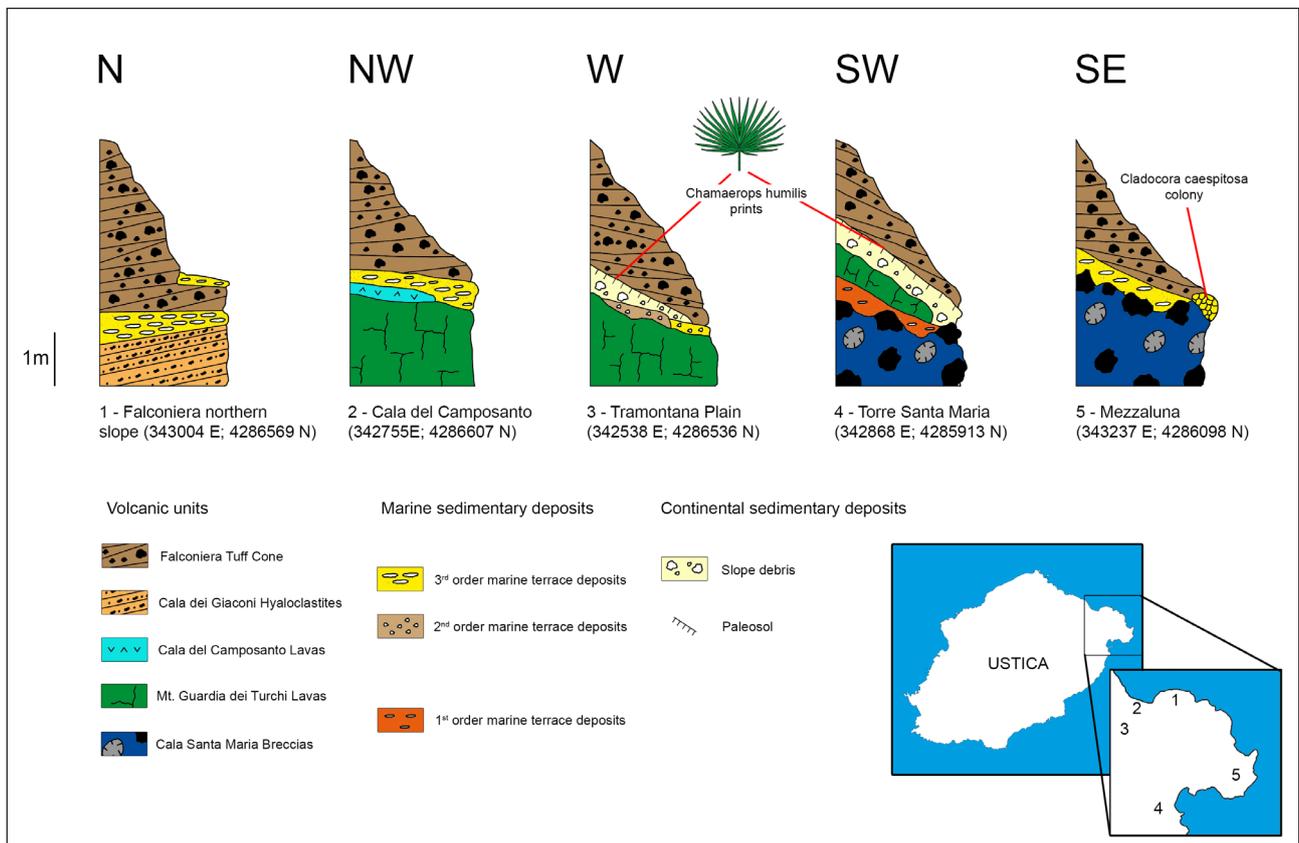


Figure 4. Scheme of the stratigraphic sequences exposed in the studied sections. Coordinate system UTM WGS84, 33S.

ter rim. The neck of the edifice is exposed at the bottom of the crater, and is composed of a columnar-jointed lava overlying the first strata of the tuff-cone close to the vent. The lava continues downward into the volcanic conduit, as a feeding dike with intrusive contacts. Lavas are light-grey in colour and porphyritic with clear olivine phenocrysts in a microcrystalline groundmass. An identical columnar jointed lava body, characterized by the same texture and mineralogy, is exposed a few tens of meters westward, in a sub-horizontal, tabular arrangement. These lavas are overlain by a discontinuous deposit of welded black scoriae of variable thickness.

The erupted products are hawaiitic in composition, with a SiO_2 content that varies from 46.36% in the pyroclastic deposits to 48.69% in the lavas erupted during the last stage of the eruption [de Vita, 1993].

4. The third order marine terrace of Ustica

The third order marine terrace is related to an Eutyrrhenian transgressive-regressive cycle that correla-

tes to the Marine Isotopic Stage (MIS) 5.5. It is widely developed along the Tramontana Plain, from the eastern end of Cala del Camposanto to Punta Testa del Rosso, with an average gradient of 3%. The terrace extends between 30 and 40 m of elevation asl and it is bordered by a gently dipping slope, which connects to the lowermost and more recent marine terrace. The marine ingressions responsible for the formation of the terrace, left a 2-6 m thick detrital deposit, mainly composed of clayey sands with rounded marine pebbles, and boulders that probably originated through the dismantling of the Mt. Guardia dei Turchi northern cliff that bordered the terrace. The inner margin of the terrace is not exposed as it was later buried by the slope debris of this cliff. The lower surface of the terrace is cut on a rocky substratum, composed of lava flows belonging to the Mt. Guardia dei Turchi and Cala del Camposanto units [Figure 2; de Vita et al., 1998].

On the opposite side, along the southern slope of the Falconiera tuff-cone, the Eutyrrhenian marine transgression has left a fossiliferous beach deposit in the

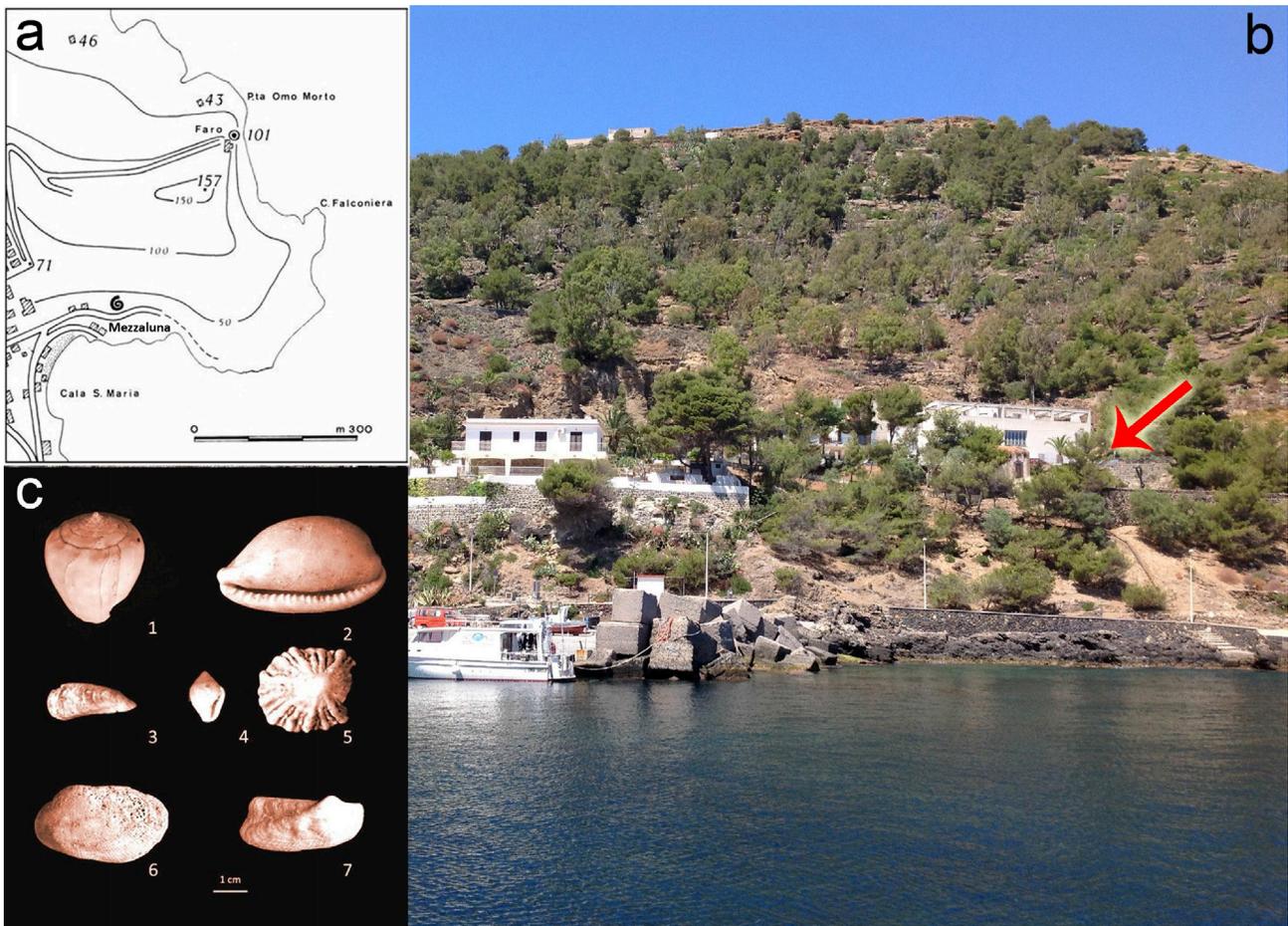


Figure 5. a) Location of the marine Tyrrhenian fossiliferous deposits at Mezzaluna [after Ruggeri and Buccheri, 1968]; b) the southern slope of the Falconiera Tuff Cone. The red arrow indicates the position of the beach deposit at about 30 m asl; c) significant specimens of the malacofauna [1- *Conus testudinarius* Hwass; 2- *Luria lurida*; 3- *Brachidontes puniceus*; 4- *Columbella rustica*; 5- *Patella ferruginea*; 6- *Barbatia barbata*; 7- *Arca noae*; after Buccheri et al., 2014].

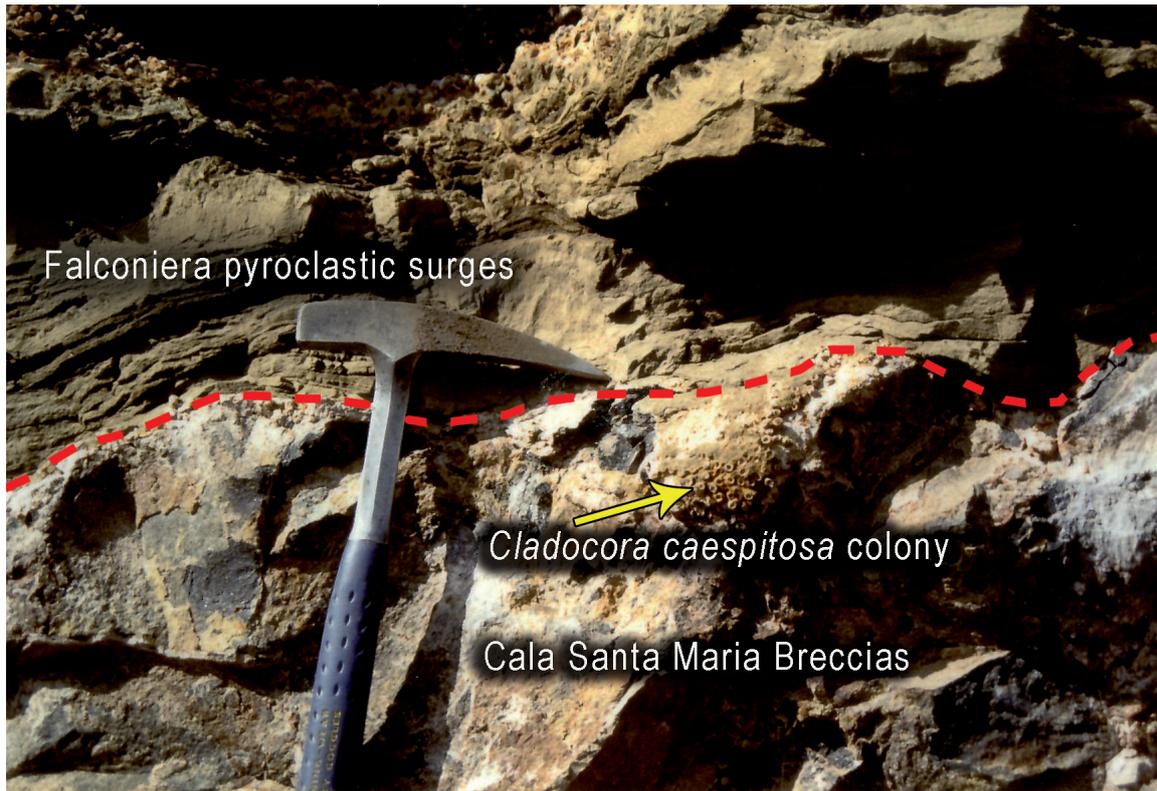


Figure 6. The *Cladocora coespitosa* colony buried under pyroclastic deposits of the Falconiera Tuff Cone at Mezzaluna (southern slope of the Falconiera Tuff Cone).

Mezzaluna site, at an altitude of about 30 m asl [Figures 5a - b; de Vita and Orsi, 1994; Buccheri et al., 2014].

The Mezzaluna fossil deposit is a very significant paleontological site, characterized by the presence of a typical, tropical-sea malacofauna, first discovered by Ruggieri and Buccheri [1968]. It contains corals, algae and mollusks such as *Strombus bubonius*, *Conus testudinarius*, *Brachidontes puniceus* and other species that are usually included in the Senegalese fauna [Figure 5c; Buccheri et al., 2014]. This malacofauna colonized the Mediterranean during the last interglacial, over a long period when the climate was warm, corresponding to the whole Tyrrhenian stage, which had its warmest peak during the Eutyrrhenian chronostratigraphic subunit [Kindler et al., 1997; Ferranti et al., 2006], between 132 and 125 ky. This subunit corresponds to the MIS 5e [Shackleton and Opdike, 1973], today referred as MIS 5.5, which was characterized by a high sea-level stand [6 ± 3 m above the present sea level in stable areas; Ferranti et al., 2006].

In the same place, at a lower altitude with respect to the previously described fossiliferous beach deposit (about 10-15 m asl), a colony of *Cladocora Caespitosa* corals has been found in its life position on a steeply dipping reef, covered by the basal layers of the Falconiera tuff-cone (Figure 6). U/Th radiometric dating performed on some specimens of these corals have in-

dicated an age of about 132 ka [de Vita and Orsi, 1994; de Vita et al., 1998].

5. The *Chamaerops humilis* leaf prints

The geological survey carried out on the island revealed the presence of a widespread paleosol at the base of the Falconiera tuff-cone deposits in their westernmost outcrops. In the Tramontana plain this paleosol developed on a detrital substratum composed of marine deposits, related to the previous, Middle-Crotonian, transgressive-regressive cycle [de Vita, 1993; de Vita and Orsi, 1994; de Vita et al., 1998]. In the western periphery of Ustica village the paleosol is developed on debris-slope deposits, representing the geomorphological evolution of the eastern slopes of Mt. Guardia dei Turchi volcano. In two outcrops the basal pyroclastic surge deposits contain abundant leaf prints, belonging to dwarf palm bushes, classified as *Chamaerops humilis* [L. Sadori pers. comm.]. The *Chamaerops humilis* is the only species of its genus and is native to the Western Mediterranean [Fedriani and Delibes, 2011]. Its present distribution is restricted to the area of origin [Medail and Quezel, 1996], both on the European side (where it is the only native palm species) and on the African side. However, at the time of the Falconiera eruption it had its maximum areal extent (Figure 7).

Chamaerops humilis is small, multi-stemmed, and



Figure 7. Suitable areas for *Chamaerops humilis*, estimated in the last interglacial (~120,000–140,000 years BP). Modified after Garcia-Castaño et al., 2014.



Figure 8. *Chamaerops umilis* leaves imbedded in the deposits of the Falconiera Tuff Cone pyroclastic surges at Tramontana.

rhizomatous, with palmate leaves [do Amaral Franco, 1980; Herrera, 1989; del Cañizo, 2011] and is characterized by variable life form, leaf colour, and by the presence of thorns [Maire, 1980]. Its optimum growing temperature is between 22–30°C. The oldest fossil records of *Chamaerops* are from the Eocene in Europe [Palamarev, 1989] and it is considered one of the most ancient fleshy-fruited species in the Mediterranean basin [Palama-

rev, 1989; Herrera, 1995]. Their fan-shaped leaves are so fibrous that the plants are quite readily preserved as fossils or prints, also within high-temperature pyroclastic density currents, as in the case of the *Ustica* specimens.

The first site of leaf-print discovery was on the eastern side of the Tramontana Plain, at about 50 m asl, in a manmade excavation, where a well-lithified succession of palagonitized grey tuffs from the Falco-

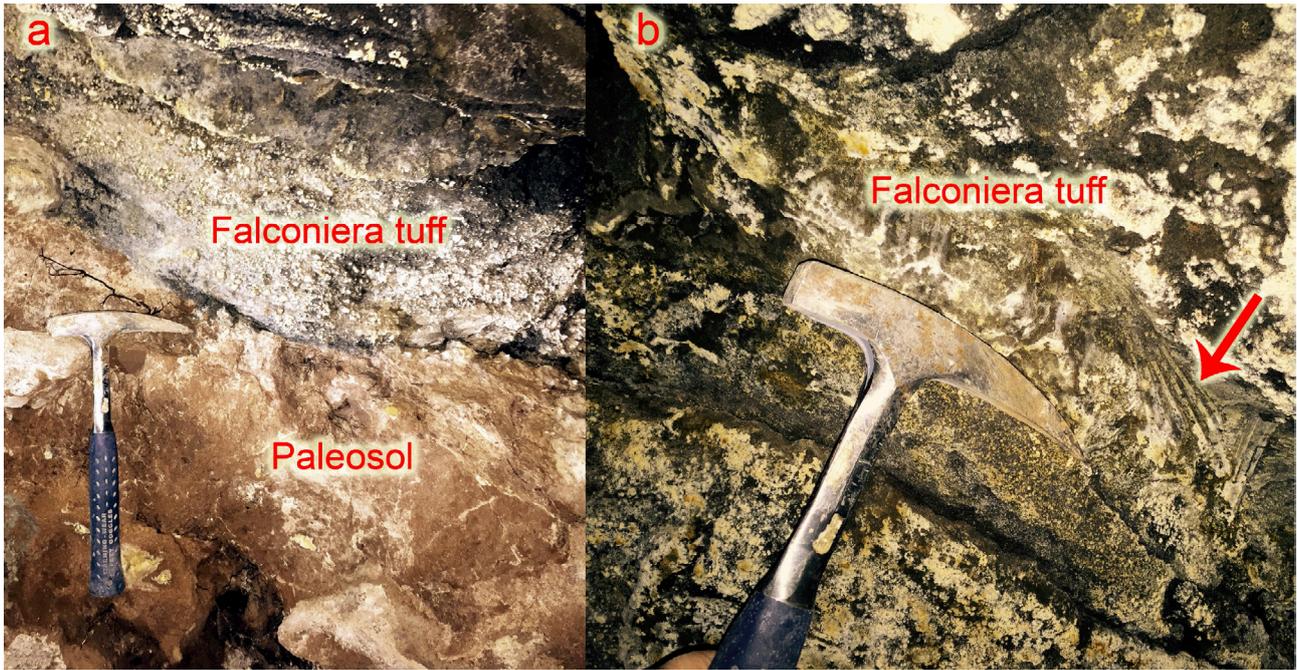


Figure 9. a) The paleosol and the overlying Falconiera tuff at Torre S. Maria (western periphery of Ustica village); b) the *Chamaerops humilis* leaves and branches, embedded in the base of the tuffs (red arrow).

niera eruption outcrops. This is one of the most distal outcrops of this unit, although the exposed succession is still more than 1 m thick and characterized by a westward low-angle dip. Numerous leaf prints have been found in this site (Figure 8), and some of them are visible in bricks used for the building of perimeter walls that separate adjacent farms.

The second outcrop is located at about 60 m asl in a cave converted into a water tank in ancient times, but presently not used. A thick and immature paleosol, varying irregularly in color from light brown at the top to yellowish at the base (Figure 9a) is exposed inside the cave. The Falconiera tuff layers overlie this paleosol, on which *Chamaerops* flourished. The remnants of abundant leaf and stem prints are widely distributed at the contact between the paleosol and the tuff (Figure 9b).

6. Discussion and conclusion

Tuff cones are usually monogenetic volcanoes, typically constructed during phreatomagmatic eruptions, in which surface water (lake or shallow-marine) is located above the vent [Cas and Wright, 1987]. The Falconiera tuff-cone succession shows a quasi-regular alternation of fine-grained, plane-parallel and cross-stratified base surge deposits, and massive to crudely stratified, coarse-ash surge and scoria fallout deposits. This kind of succession can be interpreted as the product of a pulsating energy during the eruption, in which water gained periodic access to the volcanic

conduit. This generated a series of closely-timed repetitive explosions that emplaced base surge deposits, that dispersed radially away from the vent, up to a distance <1 km. Each phreatomagmatic explosion was followed by magmatic explosions that resulted in the scoria fallout layers intercalated in the succession and partially eroded by further surge-beds. The presence of lavas and welded scoriae at the bottom of the crater suggests a general progression from phreatomagmatic to Strombolian or Hawaiian and effusive activity over time, likely representing the ponding of degassed lava, and the occurrence of occasional low-energy magmatic explosions, close to the end of the eruption. This also suggests a decrease in the water-magma interaction or the water-magma ratio toward the end of the eruption, when magma could have been cut off from the water supply, due to the emplacement of the surge beds and the construction of the cone.

The Falconiera eruption is likely to have occurred in a shallow marine environment, close to the coastline, as also testified by the sedimentary deposits lying at the base of the tuffs: the basal contact of the tuffs indicates that the lowermost surge beds were emplaced across shallow marine or beach deposits in the area close to the vent (Falconiera northern slope and Cala del Camposanto; Figure 4) and above a paleosol with palm leaf prints, and therefore in a continental environment, in more distal westernmost areas (Tramontana plain and Torre S. Maria; Figure 4); and again above beach and reef deposits in a shallow marine en-

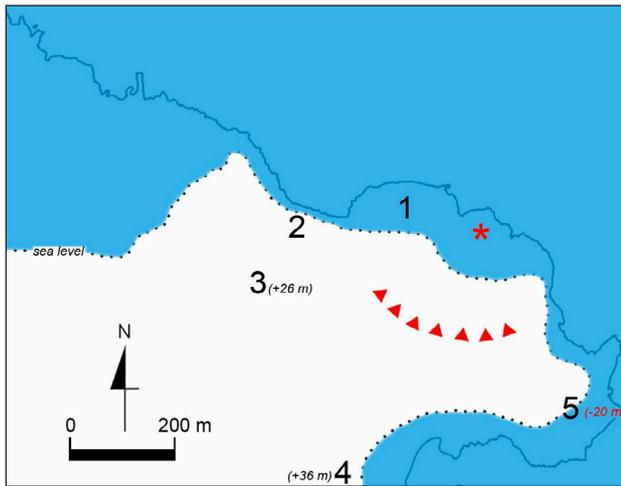


Figure 10. Reconstructed coastline at the time of the Falconiera eruption, and inferred elevation and depth of some points (see text for explanation). Numerals refer to the measured section of Fig. 4. The present coastline is reported for reference as a continuous blue line. Red triangles: Falconiera crater rim; asterisk: eruption vent.

environment, in southeasternmost proximal areas (Mezzaluna; Figure 4). Thus, interesting inferences about the palaeoenvironment at the time of the eruption can be drawn from the presence of *Cladocora caespitosa* corals. *Cladocora caespitosa* is a scleractinian coral living in the Mediterranean Sea from 5–40 m depth in turbid environments [Laborel, 1961; Zibrowius, 1980]. Large fossil formations of *Cladocora caespitosa* have been dated since the Late Pliocene characterizing the warmer climatic phases of the Pleistocene when this coral formed true reefs in both the eastern and western Mediterranean Sea [Peirano et al., 2004]. However, recent studies on the responses of these corals to sea-water warming demonstrated that if the water temperature exceeds 24–28 °C for prolonged time periods (several days), only those colonies that live at depths greater than 15 m can survive [Kersting et al., 2013]. Considering that the MIS 5.5 was characterized by a tropical climate in the Mediterranean, it can be inferred that the *Cladocora caespitosa* colony of the Mezzaluna outcrop lived between 15 and 40 m bsl. This inference fits well with the position of the Mezzaluna beach deposit, found at an elevation of 30 m asl, is that about 15–20 m above the *Cladocora caespitosa* reef. The information on the depositional environment of the Falconiera tuffs, neatly constrains the trend of the coastline at the time of the eruption to a narrow strip at the margin between continental and beach/marine deposits, in the northeastern sector of the island (Figure 10). Moreover, because during MIS 5.5 the sea level was about 6 m higher than present [Ferranti et al., 2006] and beach deposits formed during this isotopic stage are presently displaced at about

30 m asl, a total uplift of about 24 m over the past 130 ky can be estimated. Therefore, it is possible to assume that the two *Chamaerops humilis* sites of Tramontana and Torre S. Maria were located at about 26 and 36 m above the Eutyrrhenian sea level respectively, not very far from the coastline (Figure 10).

As in the case of many other similar volcanoes [Vespermann and Schmincke, 2000; Solgevik et al., 2007; Di Vito et al., 1999 and references therein; Kereszuri and Nemeth, 2012 and references therein; Coltelli et al., 2016] the Falconiera eruption could have lasted from weeks to months (including the Hawaiian/Strombolian and effusive final phases), leading to the formation of a typically asymmetric edifice, which later collapsed and opened toward the sea, as already observed for other coastal tuff-cones [Vespermann and Schmincke, 2000; Solgevik et al., 2007; Di Vito et al., 1999 and references therein]. The survival time of these edifices in areas exposed to the erosional action of the sea can be very short, in the order of few weeks or months, as demonstrated for similar island or coastal volcanoes [Solgevik et al., 2007; Falzone et al., 2009; Coltelli et al., 2016]. In the case of the Falconiera tuff-cone, we infer that sea-water gained access to the crater in a relatively brief time interval, after the end of the eruption, dismantling the northern side of the edifice and abrading the floor of the crater, leaving a flat level surface (Figure 3a) and a thin veneer of very shallow marine and beach deposits. As already stated, both the present elevation of the level surface and the fossil content are the same in the Eutyrrhenian marine terrace and deposits that underlie the Falconiera products. The same occurred along the southern side of the Falconiera promontory, at Mezzaluna, where the fossil assemblage discovered by Buccheri et al. [2014] in the marine deposits above the surge beds testifies that the normal sedimentary conditions were quite soon re-established after the eruption. There is no evidence that significant time elapsed between the eruption and the recolonization of the impacted continental environment.

Based on the volcanological, stratigraphical, geomorphological and palaeontological data outlined above, it seems reasonable that the Falconiera tuff-cone eruption had a very local and limited impact on the environment: the products were emplaced at the transition between land and sea, in both marine and continental environments, up to a distance of less than 1 km from the vent. The volcanic edifice built on by the eruption slightly modified the coastline (Figure 10), adding a small promontory to the profile of the island,

which was partly dismantled seaward in a short period. Although the products from the eruption buried beach deposits rich in mollusks, colonies of corals and subaerial plants, it seems that, at least in the submarine habitat, the pre-eruptive sedimentary and biological conditions were quickly re-established, testifying to a strong environmental resilience to the local abrupt change imposed by the eruption.

Acknowledgements. The authors are grateful to Laura Sadori (University of Rome “La Sapienza”) for the determinations on fossil leaf prints. Ilenia Arienzo (INGV – Osservatorio Vesuviano) is thanked for the chemical analyses on a tuff sample, which confirmed its attribution to the Falconiera unit. Prof. Antonella Carubba is warmly thanked for the revision of the English version of the manuscript. A special thanks is due to Giovanni Palmisano for making available his specimens of leaf prints, and to Sabino Palmisano, which allowed us access to the cave in which many leaf prints were found. We are grateful to two anonymous reviewers, whose comments and suggestions improved our manuscript.

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